Comparisons of OMI Cloud Pressures Derived from Rotational Raman Scattering with Collocated EOS Aqua/MODIS data with supporting radiative transfer calculations

Alexander Vasilkov, Joanna Joiner, Kai Yang, Robert Spurr, and P. K. Bhartia

The OMI cloud pressure products are important for correction of the mission-critical total ozone product for the ozone amount unseen by the instrument beneath clouds as well as cloud-related errors that affect the derived ozone above cloud. Here, effective cloud pressure is derived from fitting the high frequency structure of the top-of-atmosphere reflectance in the UV caused by filling in of solar Fraunhofer lines due to rotational Raman scattering (RRS) in the atmosphere. The algorithm uses the spectral range of 392-398 nm, which contains two strongest Ca lines. To reduce of the effect of dark currents on the retrievals, so called "soft calibration" is used in the algorithm. The soft calibration is based on an analysis of residuals (observed minus calculated radiances) over snow/ice scenes.

The OMI cloud pressure retrievals are compared with collocated EOS Aqua/MODIS cloud-top pressures for several events. We first examine tropical storm Arlene (June 11, 2005) and hurricane Katrina (August 28, 2005). MODIS L2 cloud-top pressures from the IR window were collocated to OMI pixels. The comparisons for Arlene revealed an interesting feature: the differences between OMI and MODIS cloud pressures for high altitude clouds with reflectivity R>80% were very small for clouds over the ocean and were as high as 300 hPa for clouds over land. A hypothesis is that two distinct layer clouds (thin ice clouds over lower water clouds) produce big differences, whereas deep convective clouds produce smaller differences.

A comparison for Katrina shows that OMI UV channels can see through high cirrus clouds to lower water clouds with the spiral band structure. At the same time, MODIS IR channels primarily see highest cirrus clouds (Fig. 1). The spiral structure is obscured by cirrus clouds, which are detectable by MODIS. The most interesting feature is that MODIS reports higher clouds than OMI does even within the hurricane eye.

We also looked at the effect of using the retrieved cloud pressures in the OMI total column ozone algorithm. Currently, the OMI ozone algorithm based on TOMS version 8 (OMTO3) utilizes climatological cloud pressures. Using the actual cloud pressures retrieved from RRS has a significant impact on total column ozone over the hurricane Katrina area (Fig. 2). Total column ozone retrieved with climatological pressures shows a false "eye" with enhanced ozone within it. The false eye is removed when ozone retrieved with cloud pressures from OMI. Also, some additional effects due to using actual cloud pressures can be seen on the map of total column ozone. First, lower values of ozone are observed due to the high tropopause in the vicinity of the hurricane. Second, higher total ozone slightly west of the eye may indicate a small amount of stratospheric intrusion near the eye.

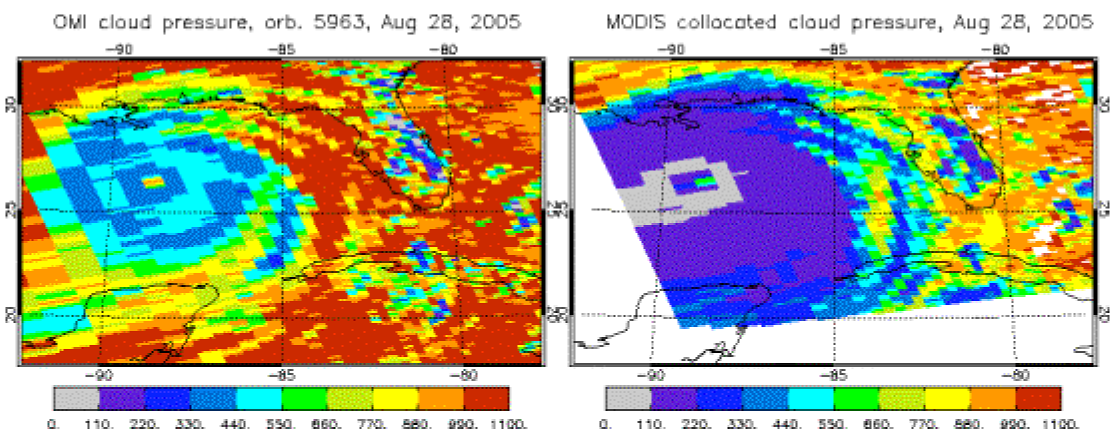

Figure 1. Hurricane Katrina: OMI effective cloud pressure (left) and MODIS cloud-top pressure (right).

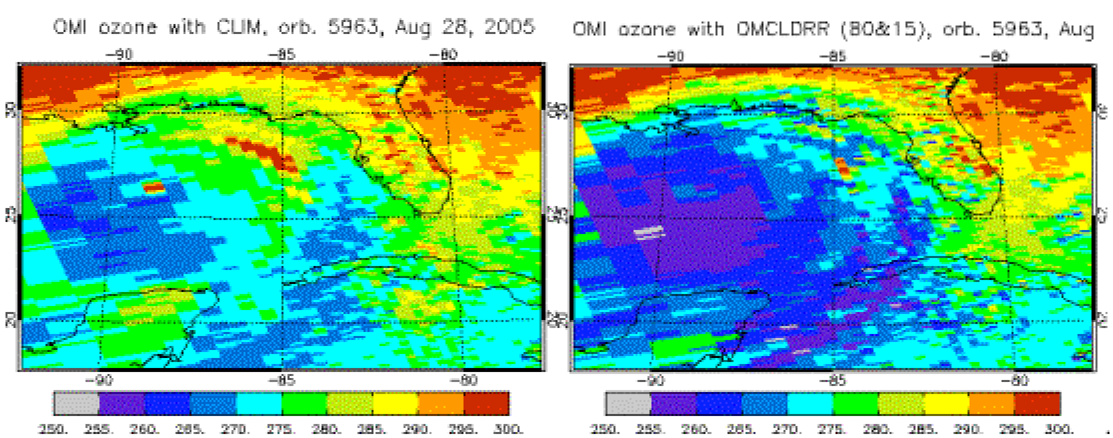

Figure 2. Hurricane Katrina: total column ozone retrieved with climatological cloud pressures (left) and actual cloud pressures (right).

The OMI cloud pressure retrievals are also compared with EOS Aqua/MODIS L2 cloud-top pressures for hurricanes Rita and Wilma (Sep-Oct, 2005). Similar to hurricane Katrina, the comparisons showed that OMI UV channels can see through high cirrus clouds to lower water clouds with the spiral band structure. At the same time, MODIS IR channels primarily see highest cirrus clouds (Fig. 3). Using the actual cloud pressures retrieved from RRS has a significant impact on total column ozone over the hurricane areas (Fig. 4). Total column ozone retrieved with climatological pressures shows a false “eye” with enhanced ozone within it. The false eye is removed when ozone retrieved with cloud pressures from OMI.

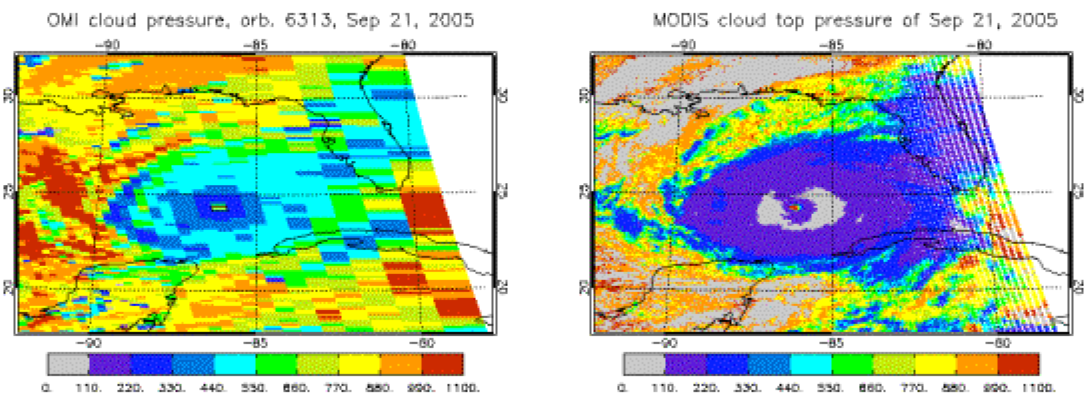

Figure 4. Hurricane Rita: OMI effective cloud pressure (left) and MODIS cloud-top pressure (right).

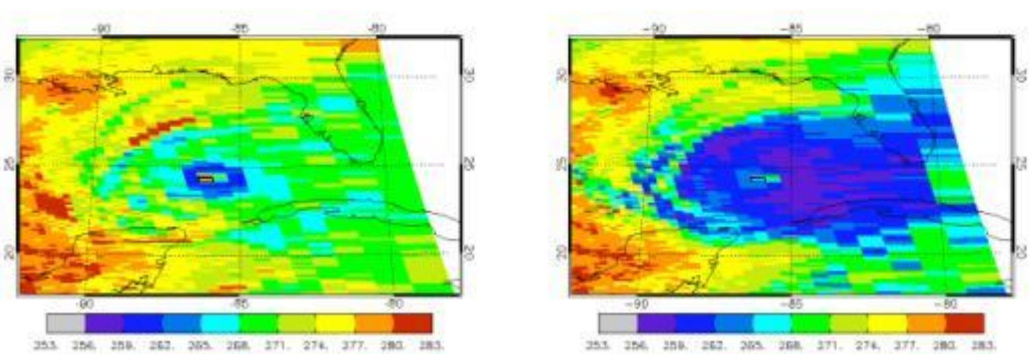

Figure 4. Hurricane Rita: total column ozone retrieved with climatological cloud pressures (left) and actual cloud pressures (right).

Concurrent estimates of cloud liquid water and ice profiles over Katrina from the tropical rainfall measurement mission (TRMM) microwave imager (TMI) clearly show a secondary cloud wall that like the primary eyewall contains ice clouds at high altitudes and water clouds below (Fig. 5). The derived cloud profiles therefore qualitatively support the horizontal structure in the OMI image and the difference between the OMI and MODIS cloud pressures.

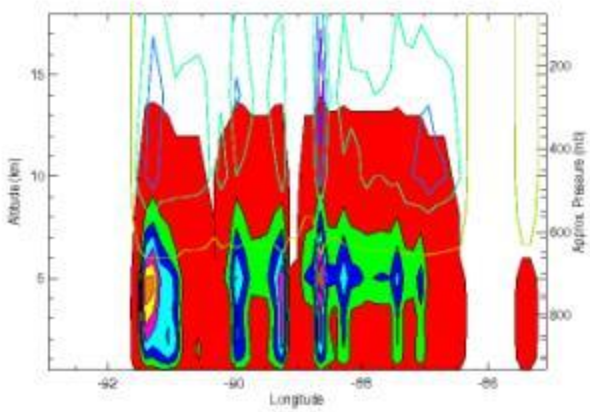

Figure 5. Cross section through Katrina of estimated cloud liquid water (filled contours with intervals of 0.04 g/m^3) and ice (colored contours lines with 0.02 g/m^3) for TRMM orbit 44373.

The OMI – MODIS cloud pressure differences depend on the type of clouds present. The large differences appear to be related to thin cirrus clouds, which do not significantly affect the OMI retrievals in the UV, but are detectable in the IR. In efforts to understand those differences, we have carried out initial radiative transfer calculations with RRS for a model of two layer clouds. In case of an optically thin lower layer, filling-in decreases monotonically with optical depth of the upper layer (green line in Fig. 6).

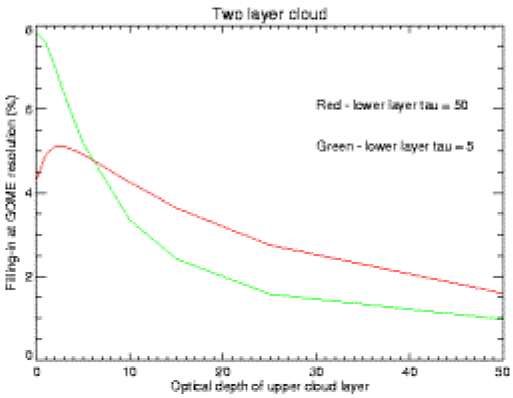

Figure 6. Filling-in at the center of the Ca Fraunhofer line (397 nm) as a function of optical depth of the upper cloud layer.

The situation is dramatically different in case of optically thick lower layer. In some range of optical depth there is an increase of filling-in due to scattering between the cloud layers (red line in Fig. 6). This case, which is realistic for hurricane clouds, has an important implication: the RRS cloud pressure algorithm will retrieve cloud pressure higher than that of lower cloud layer.

Conclusions and future work

The OMI – MODIS cloud pressure differences depend on the type of clouds present: differences for high reflectivity clouds can be small for deep convective clouds and large for two layer clouds. Those large differences appear to be related to thin cirrus clouds, which do not significantly affect the OMI retrievals in the UV, but are detectable in the IR. In water clouds, the smaller differences between OMI and MODIS cloud pressures still exist and are explained by noticeable penetration of solar light into clouds in the UV. Comparisons with NASA/Cloud Physics Lidar (CPL) data will be done, particularly because CPL can see through thin cirrus to lower water clouds. The Cloudsat/Calipso combination will also be an important data source for future validation.